

Geothermal Heat Pumps Deliver Big Savings for Federal Facilities

An update on geothermal heat pump technologies and the Super ESPC

Geothermal heat pumps (GHPs) are proving to be an energy-efficient, cost-effective choice for heating and cooling Federal facilities. GHPs heat and cool more efficiently than conventional systems, and they offer other benefits as well: they cost less to maintain, have a longer life expectancy, operate quietly, provide superb comfort, and cause less CO₂ emissions than conventional heating and cooling systems.

GHPs use the ground, rather than ambient air, as a heat source and sink, using its stable temperature to improve energy efficiency. Ground temperatures are cooler than the air in the summer and warmer during the coldest months, so GHPs benefit from cooler condensation temperatures for cooling and warmer evaporating temperatures for heating.

At the U.S. Army base in Fort Polk, Louisiana, 4,003 GHPs were installed between 1995 and 1996. This project has demonstrated the technology can yield substantial energy and cost savings for Federal facilities. The Fort Polk project reduced electricity consumption in base housing by 33% while eliminating natural gas consumption altogether. (For details, see www.eren.doe.gov/femp/financing/tecspec.html. Click on "Geothermal Heat Pumps.")

The Fort Polk project was carried out under a new financing strategy called an energy savings performance contract (ESPC). In an ESPC, an energy services company (ESCO) bears the costs of implementing energy-saving measures in exchange for fixed payments from the resulting cost savings. The U.S. Department of Energy's (DOE's) Federal Energy Management Program (FEMP) has implemented a "Super ESPC" to streamline the process of procuring GHP-centered projects. A GHP system must be the major focus, but other energy conservation measures (e.g., lighting improvements) can be included if they make the projects more economical. FEMP has selected and pre-approved a pool of ESCOs with which Federal agencies can contract. Under the Super ESPC, delivery

orders can be awarded quickly, and facility managers have the assurance that all of the selected ESCOs are qualified to deliver top-quality GHP-centered energy efficiency projects.

Advantages of GHP-Centered Projects under the Super ESPC

- Using the Super ESPC ensures alignment with ESPC statutory authority and full compliance with all Federal procurement regulations applying to performance contracting.
- GHP Super ESPC contracts were awarded to large, financially stable ESCO teams that can offer financing at low rates.
- ESCOs awarded Super ESPC contracts had to demonstrate their GHP capabilities through past projects and a specific proposal for a large initial project.
- New GHP heating, cooling, and water-heating systems can be acquired at no capital cost; improvements are funded out of energy and related operation and maintenance cost savings.

Contractors selected under the GHP ESPC

- Constellation EnergySource, Baltimore
 - Duke Solutions, Charlotte, N.C.
 - Exelon Energy Services, King of Prussia, Penn.
 - The Enron Team: Co-Energy Group, Las Vegas; Enron Energy Services, Houston; and the Bentley Company, San Ramon, Calif.
 - Trane Company Asset Management Services, St. Paul
-
- Adequate operating budgets are guaranteed. ESPC project cost savings are guaranteed to exceed payments to the ESCO for services and debt retirement in each year of the contract.
 - GHP-centered ESPCs lighten the workload of beleaguered operating and maintenance staff by renewing systems with inherently low-maintenance GHP technology.



Technology Focus

An update on technologies for energy and resource management

Prepared by the New Technology Demonstration Program

The U.S. Department of Energy requests that no alterations be made without permission in any reproduction of this document.



“These contracts alone can save each site up to 40% on its energy bills. This innovative business and technology strategy is good for taxpayers and good for the environment.”

Secretary of Energy Bill Richardson

- In-house staff may be trained to operate and maintain GHPs and other energy conservation measures. These skills can then be applied in maintaining other buildings.
- ESCPs motivate ESCOs to educate building occupants and keep them happy, because occupants affect energy consumption.

GHP System Types

Several GHP system types are allowed under the GHP Super ESPC. The common denominator is that the system moves heat between a building and one or more geothermal source/sinks—such as the ground, ground-water, surface water, wastewater streams, or potable water supplies (where allowed)—via water source heat pumps to provide services such as space heating and cooling, water heating, and refrigeration. This broad choice of GHP systems enables Super ESPC contractors and Federal sites to pick the options that make their GHP projects most economical.

Hybrid systems using several of these source/sinks, or outdoor air in combination with one or more of these source/sinks, are allowed where they make the overall GHP system more economical. Hybrid approaches are especially effective where cooling needs are significantly larger than heating needs.

A GHP system may serve one or many water source heat pumps, depending on the application. For example, military family housing might be served

with systems having one heat pump per living unit, each with its own vertical ground heat exchanger. Larger facilities might have many heat pumps on a common loop with a central variable-speed pumping station and one large geothermal source/sink.

Why GHPs Save Energy and Money

GHPs save energy and money because the equipment operates more efficiently than in conventional systems. A compressor operates much more efficiently in a water source heat pump than in an air source unit. In addition, air needs to be moved only on one side of the GHP, and less power is needed to move the water (or anti-freeze) on the other side than would be needed to move air. The geothermal source/sink is far more stable than outdoor air and has much less severe high and low temperature extremes. Unlike air source units, GHP systems do not need defrost cycles nor backup electric resistance heat at low outdoor air temperatures in most cases.

Common loop GHP systems recover heat as part of their design. In cooler weather, the heat pumps serving the building perimeter extract heat from the common loop to provide space heating, while units serving core areas are cooling space and rejecting heat to the common loop. When the common loop is in balance, no net heat exchange with the ground is required; under many operating conditions, the offset between heating and cooling units reduces the thermal load on the ground heat exchanger. Recovered heat also can be used to heat water,

using either desuperheaters on the heat pumps or dedicated water-to-water units.

GHP systems save money because they use less energy and improve energy consumption patterns. The 4,003 GHPs in family housing at Fort Polk reduced the summer electric peak demand of that city of 12,000 people by 7.5 MW (43%) and increased the annual electric load factor from 0.52 to 0.62. Federal sites may be able to purchase electricity at lower costs when their load characteristics improve so dramatically.

Maintenance Benefits of GHPs

Lower maintenance costs are another advantage GHPs have over conventional systems. An analysis of 1996–1998 maintenance work records for the Lincoln, Nebraska, school district shows that annual corrective maintenance (repair) costs for four GHP-equipped schools averaged 2.1 cents/ft², compared with 2.9 to 6.1 cents/ft² for conventional systems in 16 other schools. Another analysis by the Geothermal Heat Pump Consortium found average total (preventive and corrective) maintenance costs for 25 GHP-equipped buildings to be about



Drilling rigs installing borehole heat exchangers at Fort Polk, Louisiana.

11 cents/ft²—16 to 30 cents/ft² less than for conventional systems. Both studies are published by ASHRAE (1998, 1999); see citations on the last page.

Technical Feasibility of GHPs at Federal Sites

For the government to receive the best value from GHP technology, the ESCO and Federal site personnel need to determine which GHP system or combination of systems is most economical for each site. The order of preference is not universal, but it generally is as follows.

Groundwater already being pumped. Is groundwater currently being pumped to the surface? Some Federal sites pump groundwater to the surface, treat it, and re-inject it as

a part of groundwater remediation projects in areas near buildings. Tapping into already existing heat source/sinks may be economical. A heat exchanger (typically the plate-and-frame type) can be used to transfer heat between the groundwater and a common loop serving water source heat pumps in nearby buildings. After remediation is completed, pumping on the groundwater side of the heat exchanger can be re-optimized for the HVAC application and continued using the same supply and reinjection wells.

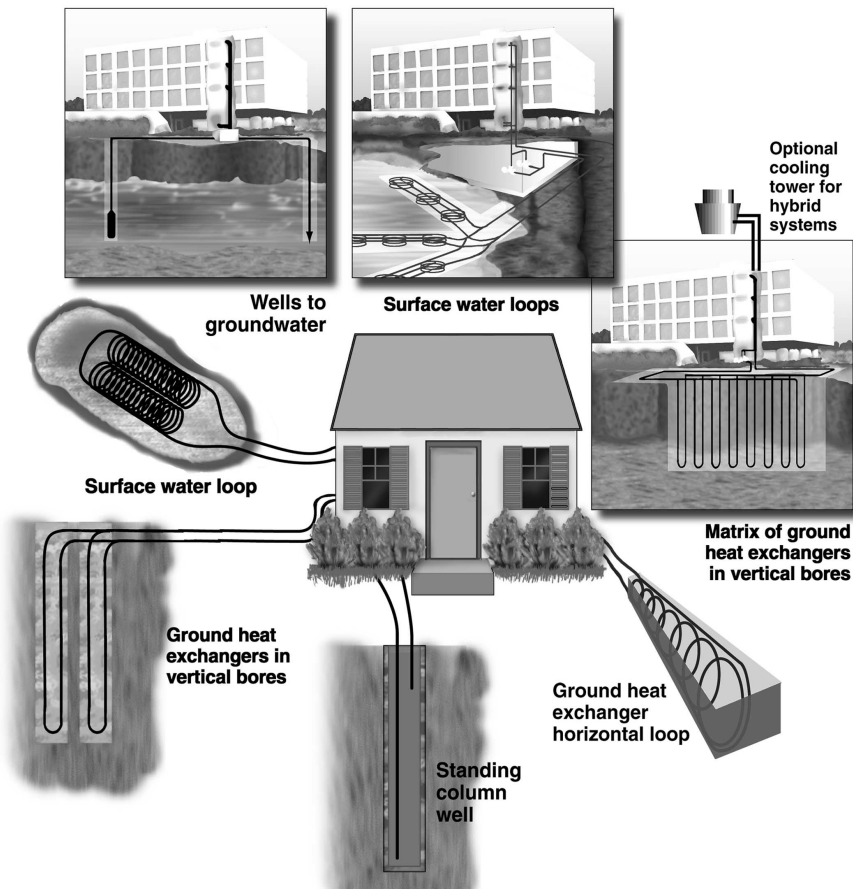
Stationary surface water. Are large volumes of stationary surface water on the site, owned by the government and with government use restrictions, near buildings with significant heating and cooling loads? It may be economical to use surface

water impoundments such as reservoirs, runoff retention basins, reflecting pools, ponds, and lakes for heat exchange. A common loop serving water source heat pumps in nearby buildings can be submerged directly into the body of water. If the water is used for recreational or other purposes that might interfere with this approach, an on-shore pump house with a heat exchanger and protected intake from and discharge to the body of water could be considered.

Moving surface water. Are large volumes of reliable moving surface water (e.g., large rivers with reliable flow and modest current), owned by the government and with government use restrictions, on the site near buildings with substantial space? An on-shore pump house with a heat exchanger and protected intake from and discharge to the moving body of water could be considered. Issues such as historical high and low water conditions, debris flow, and commercial and recreational traffic would require serious attention.

Wastewater streams. Does the site have large-volume, reliable flowing wastewater streams near buildings with significant square footage? A common loop serving water source heat pumps in nearby buildings could be conditioned by a heat exchanger in contact with the wastewater. Heat exchanger maintenance must be considered, as well as the stability of the missions of the facilities that are the source of the wastewater.

Groundwater. Are large quantities of groundwater available at a reasonable depth, as well as an acceptable and economical means of disposal, near buildings with significant heating and cooling loads? The groundwater can be used with a heat exchanger to condition a common loop serving water source heat pumps in nearby



buildings. Poor water quality might require the use of expensive heat exchanger materials, and additional maintenance and aquifer re-injection in some formations might be expensive.

Standing column well.

Standing column well GHP systems are similar to standard groundwater GHPs, but because water is recirculated between the well and the building, only one well may be required (larger projects may have several wells in parallel). Standing column wells are feasible in areas with near-surface bedrock. Deep bores are drilled, creating a long standing column of water from the static water level down to the bottom of the bore. Water is recirculated from one end of the column to the other. During peak heat rejection or extraction periods, the system can bleed part of the water rather than reinjecting it all, causing water inflow to the column from the surrounding formation. This cools the column during heat rejection, heats it during heat extraction, and reduces the required bore length.

Ground heat exchangers (or ground loops).

Does the site have sufficient land area near buildings with significant square footage to accommodate ground heat exchangers? If so, heat exchange with the ground, using vertical or horizontal loops, may be economical. Horizontal loops require considerably more land area but may be less expensive to install, depending



GHP technology is saving energy and money in the Oklahoma State Capitol (above) typical of many historic government buildings.

on the types of soil and rock formations encountered in drilling.

Ground heat exchangers are an option almost anywhere. They are listed last not because they are less economical, but merely to ensure that other geothermal options that may be even more economical are considered where they exist.

References

Martin, M. A., D. J. Durfee, and P. J. Hughes, "Maintenance Study of Geothermal Heat Pump Systems in Lincoln Public Schools: Repair, Service, and Corrective Actions," ASHRAE Transactions, 105, pt. 2, 1999.

Cane, E., A. Morrison, and C. J. Ireland, "Maintenance and Service Costs of Commercial Building Ground-Source Heat Pump Systems," ASHRAE Transactions, 104, pt. 2, 1998.

GHP and ESPC Information

www.eren.doe.gov/geothermal

www.geoexchange.org

www.igshpa.okstate.edu

www.eren.doe.gov/femp/financing/ghp.html

www.eren.doe.gov/femp/financing/tecspec.html#ghp

For More Information

FEMP Help Desk

(800) 363-3732

International callers please use

(703) 287-8391

Web site: www.eren.doe.gov/femp

General Contacts

Ted Collins

New Technology Demonstration

Program Manager

Federal Energy Management Program

U.S. Department of Energy

1000 Independence Ave., SW, EE-92

Washington, D.C. 20585

Phone: (202) 586-8017

Fax: (202) 586-3000

theodore.collins@ee.doe.gov

Steven A. Parker

Pacific Northwest National

Laboratory

P.O. Box 999, MSIN: K5-08

Richland, WA 99352

Phone: (509) 375-6366

Fax: (509) 375-3614

steven.parker@pnl.gov

Technology-Specific Super ESPC

Tatiana S. Muessel

U.S. Department of Energy

Forrestal Building, MSIN: 6B-052

Washington, D.C. 20585

Phone: (202) 586-9230

Fax: (202) 586-3000

tatiana.muessel@hq.doe.gov

Doug Culbreth

Contracting Officer's Representative

National Technology-Specific GHP

Super ESPC

221 Elwood Dr.

Raleigh, NC 27609

Phone: (919) 782-5238

Fax: (919) 788-0996

carson.culbreth@hq.doe.gov

Technical Contact

Patrick Hughes

Oak Ridge National Laboratory

1 Bethel Valley Rd.

P.O. Box 2008, Bldg. 3147,

MSIN: 6070

Oak Ridge, TN 37831-6070

Phone: (423) 574-9337

Fax: (423) 574-9329

pj1@ornl.gov



Produced for the U.S. Department of Energy (DOE) by the Oak Ridge National Laboratory

July 1999